

Interpretation of VLBI Results in Geodesy,
Astrometry and Geophysics

On Construction of ICRF-2

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Abstract. In this paper, several issues are considered, related to the construction of the next ICRF generation, ICRF-2. Between them, the following points are touched: ICRF-2 structure, ICRF Core sources selection, and some expected user's requirements.

1. Introduction

By now, more than 6 million geodetic and astrometric VLBI observations were made, much more than were available for the construction of ICRF, and methods of data analysis were substantially advanced. This opens up new opportunities for ICRF improvement. For this purpose, two ad hoc Working Groups were organized by IAU, and jointly IERS and IVS¹, and preparation to ICRF-2 creation was started [1]. In particular, one of the main tasks of the preparation campaign is to investigate possible strategies that are or may be used for ICRF-2, the second ICRF realization. In this paper several issues related to construction of ICRF-2 are touched.

2. ICRF-2 Structure

It is suggested that ICRF-2 comprises two source lists. The first list may be called ICRF Core. The main features of the ICRF Core are:

- realizes ICRS definitions;
- consists of about 400 sources evenly distributed over the sky, i.e. 1 source per 100-deg²;
- provides the long-time system stability.

The second list may be called ICRF Extension or ICRF Supplement. The main features of the ICRF Extension are:

¹<http://rorf.usno.navy.mil/ICRF2/>

- consists of about 3600 sources;
- keeps ICRF system;
- provides ICRF densification for extended user's needs;
- serves as a set of calibrators for the phase reference VLBI;
- may have more dense source distribution in the ecliptic belt to be used in the space navigation.

These two lists give 4000 sources in total, i.e. 1 source per 10 deg². Suggested total number of sources is close to the number of sources already observed in the IVS and VCS sessions, and for most of them reliable positions are derived, mostly for declination > -40 deg.

It seems to be reasonable to schedule in 2008 several dedicated IVS sessions to obtain positions for 300–500 sources with reasonable precision in the southern hemisphere zone with declination < -40 deg to complete ICRF Supplement list in the sky regions poorly filled with astrometric radio sources.

In principle, it is advisable to have as many Core sources as possible in order to minimize the impact on the individual source instability. At the moment, 400 sources may be a good compromise between this requirement and the real number of the well observed sources. As the VLBI system becomes more sensitive, which allows us to observe more weak compact sources, and number of well observed and investigated sources grows new sources should be included in the ICRF Core catalog to provide better system stability. However, it is important to add new sources to the ICRF Core in such a way to keep uniform distribution of the Core sources over the sky.

3. Core Source Selection

A key issue is how to select ICRF-2 Core sources. Different criteria for source selection have been proposed by many authors, based on:

1. time series analysis: velocity of the apparent source motion, scatter parameters (indices) such as (w)rms, χ^2 and Allan deviation; other statistics;
2. observation history: time span of observations, number of sessions or observations (correlation between them is at a level of 0.9), observation density, etc.;
3. physical characteristics: structure index, redshift;
4. other criteria, e.g. position uncertainty from global analysis.

In this paper only criteria of the first two groups are considered. These criteria were applied to the time series submitted by IVS Analysis Centers to the ICRF-2 data pool. For all the computations, original source positions derived from analysis of single session and reported by the analysis centers were used. Reported uncertainties in the source positions were used for weighting.

For the criteria of the first group, when possible, 2D estimates were used, e.g. source velocity was computed as $V = \sqrt{(V_\alpha \cos \delta)^2 + V_\delta^2}$, WRMS of source position computed analogously, Allan deviation computed using the

2D weighted estimate WMADEV as developed in [2]. The uncertainty in the velocity estimate was also used as a new scatter index.

The first conclusion made from this analysis is that source behavior and consequently source position variation (scatter) indices may differ significantly between the analysis centers, as can be seen from Fig. 1, 2.

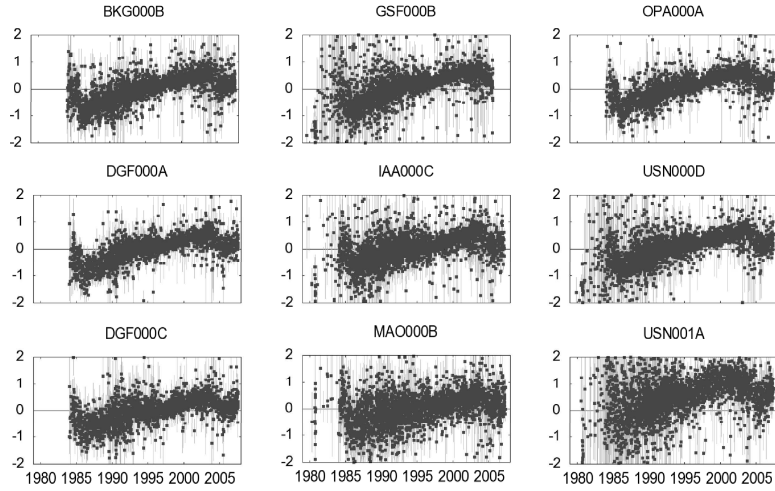


Figure 1. Several time series for 0923+392 (3C39.25) RA. In this example, several solutions show similar behavior of the source coordinate but different scatter

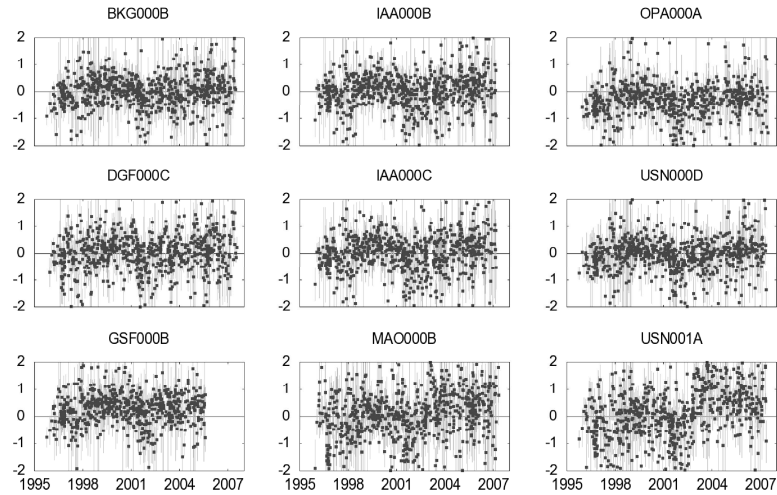


Figure 2. Several time series for 0003-066 DE. In this example, several solutions show both different behavior of the source coordinate and scatter

In Tabl. 1 an example is given for velocity estimate using several time series.

Table 1. 2D velocity of the source 0656+082 computed from different source position time series

Series	Nepochs	V, $\mu\text{as/yr}$
mao000b	197	45 ± 38
usn000d	189	53 ± 28
dgf000a-g	188	80 ± 30
opa001a	186	101 ± 29
iaa000c	168	107 ± 24
usn001a	189	124 ± 43
iaa000b	168	163 ± 24
aus001a	179	165 ± 42
gsf000b	131	235 ± 50

As can be seen from Tabl. 1, despite large number of epochs and considerable time span about 7.5 y, velocity estimates for source 0656+082 differ by several times, which shows that analysis strategy has large impact even on the estimated radio source velocity, a parameter, which is often attributed to physical processes such as jet motion, and which should seem most robust with respect to the analysis strategy. Large difference between available time series can be observed also for other scatter indices, cf. also Fig. 1, 2.

So, results of source position time series analysis heavily depend on method used for time series computation and should be used with care. Under this circumstance, maybe the number of sessions, network diversity and time span should be a first criteria to select ICRF Core candidates. Only sufficient time span and number of sessions can provide reliable conclusion on the source position variations. This inference can also be drawn from the position time series for some sources where one can see quite different velocity and scatter at different part of the interval of observations.

At the first glance we can find sufficient number of sources with large observations history, see e.g. Fig. 3, but only at the first glance. The well known problem is that distribution of the well observed sources are far from uniform, with clear deficiency in the southern hemisphere.

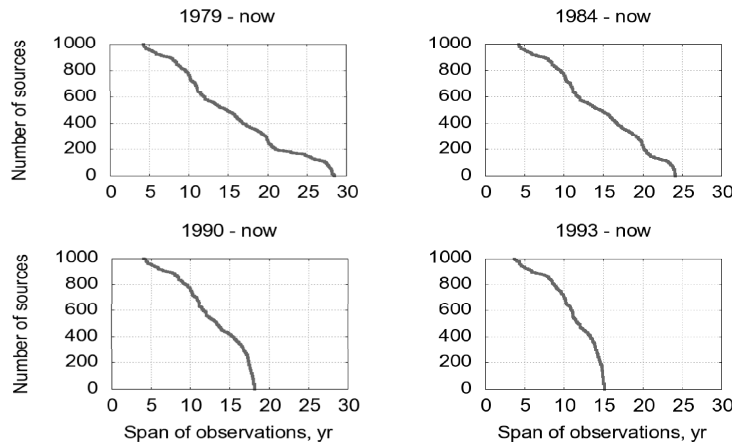


Figure 3. Number of sources for given start epoch and data span. Four plots are shown for different criteria for the data selection discussed in literature

Evidently, at the moment we have not enough sources of the highest quality (compactness and position error) to fill in all the evenly distributed 100-deg² sky cells. The following strategy for the nearest years can be considered:

- for the first ICRF-2 version, one, the best of available, source in each 100-deg² cell should be taken; at this stage a list of sources of insufficient quality (time span, number of sessions, position error) is identified;
- at the next stage, the sources of insufficient quality should be observed in 2009-2010 to be able to issue the second version of ICRF-2 by the end of 2010–beginning of 2011.

This should be mentioned that if two or more good sources fell to the same cell, they will not be lost for users since they will be included in the ICRF Extension. The general logic of this approach is to give priority to even source distribution, which presumably has advantage in maintenance of the ICRF orientation and further comparison with GAIA CRF realization.

4. ICRF for Users

From user's point of view, a source position catalog is a tool to predict the source coordinates at given epoch with known error. Currently, a user can use the source position error given in the catalog. These errors are usually obtained from least square adjustment, and can be considered as the precision only. To assess the accuracy of the source coordinates, one can analyze the source coordinates time series. For example, the uncertainty in the position of the source 0923+392 (3C39.25) given in the ICRF-Ext.2 catalog is 0.035 mas. However, one can see from Fig. 1 that this value is well underestimated, and actual position error for certain epochs may be as large as 1 mas. The error in source position based on time series analysis may be computed by the method proposed in [3], which allows us to account for both precision and scatter of the session position estimates.

Based on this considerations we can conclude that the End User Error (EUE) concept, based on the realistic estimate of the source position accuracy, may be more adequate for ICRF instead of or in addition to the *defining* or *stable* concepts, since it show just what a user gets using the catalog. Also, we can consider the Index of Position Variability (IPV) based on existing and/or new methods of analysis and computed as a continuous function, instead of the stepwise index 1-2-3-... widely used now, which should be given in a ICRF catalog to give a user a quantitative measure, or at least an impression, of the real error in the source position.

References

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- [3] Malkin, Z. Proc. 15th Working Meeting on EVGA. Barcelona, 2001, 55.